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BEHAVIORAL CONTRAST FOR KEY PECKING AS A FUNCTION OF COMPONENT DURATION WHEN ONLY ONE COMPONENT VARIES

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Pigeons pecked keys for food reinforcers delivered by multiple variable-interval 2-min variable-interval 2-min schedules. Positive behavioral contrast was created by changing one component to extinction; negative contrast was achieved by changing one component to a variable-interval 15-s schedule. The duration of each component was varied independently of the other from 5 to 960 s. The size of positive contrast was greatest when the extinction component was 30 or 60 s long. It did not change significantly with changes in the duration of the variable-interval 2-min component. The absolute size of negative contrast decreased with increases in the duration of the variable-interval 2-min component. It did not change significantly with changes in the duration of the variable-interval 15-s component. These results show that the size of contrast is determined primarily by the duration of the component that provides the less favorable conditions of reinforcement. These results are not predicted by current theories.

Key words: behavioral contrast, component duration, multiple schedule, variable-interval schedule, key peck, pigeons

Behavioral contrast is frequently studied in operant psychology. The term refers to an inverse relation between the rate of responding in one component of a multiple schedule and the conditions of reinforcement in the other component. Positive contrast is an increase in first-component responding with a worsening of second-component reinforcers. Negative contrast is a decrease in first-component responding with improvements in second-component reinforcers (e.g., McSweeney & Norman, 1979).

The absolute sizes of both positive and negative key-peck contrast generally decrease with increases in component duration (e.g., McSweeney, 1982; McSweeney & Melville, 1988). The studies that have measured these changes have usually set the duration of the two components equal to each other and have varied the duration of both components. The present experiments varied the duration of each component separately. We asked whether changes in the duration of one particular component produce the changes in contrast. Throughout this paper, the component in which contrast is measured will be called the *contrast* component. The component that is altered to produce contrast will be called the *variable* component.

These experiments test a fundamental assumption of most theories of contrast. Most theories assume that positive and negative contrast are produced by symmetrical theoretical mechanisms. For example, positive contrast has been attributed to decreases in the rates of reinforcement obtained from the other component (Herrnstein, 1970; Williams, 1983), to decreases in competition from other responses (Hinson & Staddon, 1978), to the addition of responses controlled by the stimulus–reinforcer relation to instrumental responses (e.g., Rachlin, 1973), to decreases in the amount of suppression from following reinforcers (McSweeney, 1987), and to decreases in competition from unprogrammed reinforcers (McLean & White, 1983). Negative contrast is usually attributed to the opposite. That is, negative contrast may be produced by an increase in the rate of reinforcement obtained from the other component, by an increase in competition from other responses, by responses controlled by the stimulus–reinforcer relation that interfere with instrumental responses, by increases in suppression by following reinforcers, or by increases in competition from unprogrammed reinforcers.

Theories of symmetry have gained support from several studies. These studies have shown that changes in an independent variable, such as component duration, alter positive and neg-

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Table 1

Response rates (in responses per minute) emitted by each subject during each component of each schedule in Experiment 1. The standard deviations appear in parentheses.

		Positive contrast					
		Subject					
		83002		83004		83005	
Duration	Component	Baseline	Contrast	Baseline	Contrast	Baseline	Contrast
5 s	contrast	57.3 (5.6)	51.3 (4.5)	45.4 (1.9)	50.2 (6.0)	37.9 (4.8)	46.4 (13.5)
	variable	64.5 (4.2)	52.5 (7.0)	38.9 (7.6)	11.4 (4.7)	48.2 (3.6)	22.8 (10.9)
30 s	contrast	72.9 (8.2)	93.3 (3.9)	55.8 (16.8)	117.5 (9.8)	25.3 (19.4)	56.6 (40.6)
	variable	54.6 (13.1)	17.8 (4.4)	20.7 (0.9)	27.9 (6.6)	9.6 (6.8)	6.3 (9.8)
60 s	contrast	39.0 (10.6)	59.8 (7.5)	27.7 (7.7)	57.2 (11.0)	18.2 (4.9)	39.2 (18.7)
	variable	43.0 (11.4)	42.6 (6.3)	25.4 (6.5)	30.7 (3.2)	30.1 (7.8)	12.3 (7.1)
180 s	contrast	95.2 (26.2)	117.3 (16.0)	78.6 (23.6)	71.5 (23.8)	29.4 (8.5)	35.0 (12.6)
	variable	52.2 (10.0)	35.6 (13.3)	37.7 (6.6)	25.6 (6.4)	38.8 (4.1)	17.0 (14.4)
960 s	contrast	116.4 (31.9)	98.4 (22.9)	54.0 (16.3)	60.8 (12.0)	33.2 (14.3)	60.8 (7.4)
	variable	29.6 (3.8)	17.1 (2.4)	32.1 (2.7)	11.1 (4.3)	47.0 (5.0)	20.2 (3.7)

ative contrast in a similar way (e.g., McSweeney, 1982; McSweeney, Dougan, Higa, & Farmer, 1986; McSweeney & Melville, 1991a). In contrast, few data suggest that asymmetrical mechanisms are involved (but see Schwartz, 1975).

The present experiments provide another test of the symmetry theories. The sizes of positive and negative contrast were studied as a function of the duration of the variable component in Experiment 1 and as a function of the duration of the contrast component in Experiment 2. If the symmetry theories are correct, then changes in the duration of either component should alter the size of both positive and negative contrast in similar ways.

The present experiments used a within-session method of measuring contrast. Within-session procedures have been used in the past (e.g., de Rose, 1986; McSweeney & Melville, 1988, 1991a, 1991b; Williams, 1979), but most studies of contrast use across-session procedures. Across-session procedures modify the reinforcement provided by one component across successive phases from baseline to contrast and then back to baseline (e.g., McSweeney et al., 1986). Within-session procedures measure contrast and baseline within single sessions.

The within-session procedure was developed to deal with two problems that have discouraged functional studies of contrast in the past. First, the across-session procedure requires many sessions. Each measurement of contrast requires exposure to a multiple schedule in each of three phases, with each phase often lasting 30 to 40 sessions. Experiments that use this procedure may become prohibitively long if several measurements of contrast are desired. Second, fluctuations in responding that occur over these long periods confound the measurement of contrast. Rates of responding may double from one baseline schedule to its recovery (e.g., McSweeney et al., 1986; Spealman & Gollub, 1974), severely limiting the accuracy of quantitative statements.

The within-session procedure addresses these problems. It delivers a baseline schedule in the first half of the session and a contrast schedule in the second half. Because it measures baseline and contrast within single sessions, it reduces both the amount of time required to measure contrast and the fluctuations in responding that occur over time.

The details of the present within-session procedure (e.g., order of components, session lengths) have been empirically developed to produce orderly results that resemble those produced by the across-session procedure. For example, the median sizes of positive key-peck contrast reported using an across-session (McSweeney, 1982) and the present within-session procedure (McSweeney & Melville, 1988, Experiment 3) were 1.66 and 1.51 when both components were 5 s long, 1.43 and 1.43 when both components were 30 s long, and

Table 1 (*Continued*)

Negative contrast					
Subject					
83002		83003		83004	
Baseline	Contrast	Baseline	Contrast	Baseline	Contrast
52.8 (13.0)	43.4 (8.1)	62.3 (8.3)	60.0 (10.4)	22.7 (6.5)	23.1 (4.9)
72.2 (28.3)	80.9 (19.1)	143.6 (23.2)	176.6 (3.0)	25.8 (22.2)	50.3 (28.5)
31.7 (5.4)	16.4 (4.9)	19.0 (5.7)	21.1 (3.0)	25.4 (10.8)	22.2 (3.5)
47.0 (7.6)	73.0 (9.6)	40.9 (6.9)	146.2 (6.1)	29.0 (7.9)	46.1 (5.7)
31.5 (13.5)	19.7 (8.6)	49.0 (12.0)	26.3 (4.6)	6.7 (4.1)	3.1 (1.7)
31.2 (15.3)	59.1 (16.6)	103.8 (37.6)	140.9 (13.3)	19.8 (12.9)	36.2 (15.0)
56.5 (17.1)	32.9 (9.1)	9.7 (4.2)	5.4 (2.9)	17.6 (3.0)	14.5 (2.0)
39.4 (6.1)	35.6 (8.2)	32.5 (31.0)	41.9 (21.0)	17.2 (1.2)	22.7 (7.1)
37.2 (25.8)	20.0 (15.2)	23.6 (9.7)	15.6 (4.3)	0.0 (0.0)	0.8 (1.1)
12.5 (6.7)	36.2 (7.9)	39.2 (19.4)	99.8 (15.9)	10.8 (6.8)	26.6 (17.9)

1.13 and 1.24 when both components were 3 min long. The size of positive contrast was measured (as it was throughout this paper) by dividing the rate of responding during the variable-interval (VI) component of a multiple VI extinction schedule by the rate of responding during the same component of a multiple VI VI schedule. These similarities in the size of contrast occurred despite many other procedural differences between the two studies.

EXPERIMENT 1

In Experiment 1, we examined the size of positive and negative key-peck contrast as a function of the duration of the variable component.

Method

Subjects. Four experimentally experienced pigeons, maintained at approximately 85% of their free-feeding body weights by postsession feedings, served as subjects. Three were exposed to the procedure used to produce positive contrast, and 2 of these 3 plus 1 other were exposed to the procedure used to produce negative contrast.

Apparatus. The apparatus was a standard three-key operant conditioning unit for pigeons, measuring 30 cm by 36 cm by 27 cm. Three Plexiglas response keys (2.5 cm diameter) appeared 3 cm below the ceiling. The left and right keys were 7 cm from the side walls, and the center key was midway between them. An opening (4.5 cm by 5 cm), located 7.5 cm above the floor and midway between the two sides, allowed access to the food magazine. A Plexiglas panel (4 cm diameter) was 0.5 cm from the right side wall and 1.5 cm from the ceiling. A 2.8-W light located behind this panel served as a houselight.

The experimental enclosure was housed in a sound-attenuating chamber. A ventilating fan masked outside noises. A SYM® microcomputer, located in another room, scheduled the experimental events and recorded the data.

Procedure. Subjects had pecked keys in previous experiments; therefore, they were placed directly on the current procedures. During the procedure used to produce positive contrast, the first part of each session (baseline) presented a multiple VI 2-min VI 2-min schedule. The second part (contrast) presented a multiple VI 2-min extinction schedule. Both components were presented on the center key. A red light (1.12 W) appeared on this key when the first component was available. A green light (1.12 W) appeared when the second component was available. The components alternated.

The duration of the contrast component was held constant at 30 s, and the duration of the variable component changed. The following variable-component durations were presented in the following order: 60 s (24), 30 s (36), 180 s (10), 5 s (60), and 960 s (2). (The number

in parentheses following each duration is the number of components that were presented in each of the baseline and contrast phases of each session. This number varied across experimental conditions to hold session length approximately constant.) Each variable-component duration was presented for 30 sessions.

Reinforcers consisted of 5 s of access to a magazine that contained mixed grain. They were scheduled by a 25-interval series constructed according to the method of Fleshler and Hoffman (1962). Reinforcers that were scheduled but not collected before a component changed were held over for the next presentation of that component. Sessions were conducted five to six times per week.

The procedure used to produce negative contrast was identical to that for positive contrast except that the contrast phase of the session presented a multiple VI 2-min VI 15-s schedule. The following durations of the variable component were presented in the following order: 180 s, 30 s, 960 s, 5 s, and 60 s.

Results and Discussion

Table 1 presents the rates of responding (in pecks per minute) for each subject responding on each component of each multiple schedule. Response rates were calculated by dividing the number of pecks during a component by the time for which that component was available (excluding hopper-presentation time). The results presented in Table 1 are the means of the rates during the last five sessions of exposure to each component duration.

Table 1 shows that responding was stable. The standard deviations of the response rates (M = 10.6) were small relative to the rates themselves (M = 43.6). Table 1 also shows that the schedules controlled behavior. The response rates during the variable components decreased when that schedule changed from VI 2 min to extinction in 13 of 15 cases for individual subjects. Variable-component response rates increased when that component changed from VI 2 min to VI 15 s in 14 of 15 cases for individual subjects.

Discrimination was also good during the contrast schedule. The rates of responding during the VI 2-min components were greater than the rates during the extinction components of the contrast schedules in 14 of 15 cases. The only exception occurred for Subject 83002 when the variable component was 5 s long. The rates of responding during the VI 15-s components were greater than the rates during the VI 2-min components of the contrast schedules in all 15 cases. However, the difference in response rates was small for Subject 83002 when the variable component was 180 s long.

Positive and negative contrast occurred often (Table 1). The rates of responding during the constant contrast component increased in 12 of 15 cases for individual subjects when the schedule provided by the variable component changed from VI 2 min to extinction (positive contrast). The rates of responding during the contrast components decreased in 12 of 15 cases for individual subjects when the schedule provided by the variable component changed from VI 2 min to VI 15 s (negative contrast).

Figure 1 presents the size of positive and negative contrast plotted as a function of the duration of the variable component (in seconds). Calculations were based on the data reported in Table 1. The size of negative contrast was not plotted for the 960-s components for Subject 83004, because this subject stopped responding during the contrast components for this schedule. It should be noted that different subjects generated the results for positive and negative contrast presented in the bottom two graphs.

Figure 1 shows that the absolute sizes of both positive and negative contrast were greatest when components were 30 or 60 s long. That is, the points plotted in Figure 1 fall

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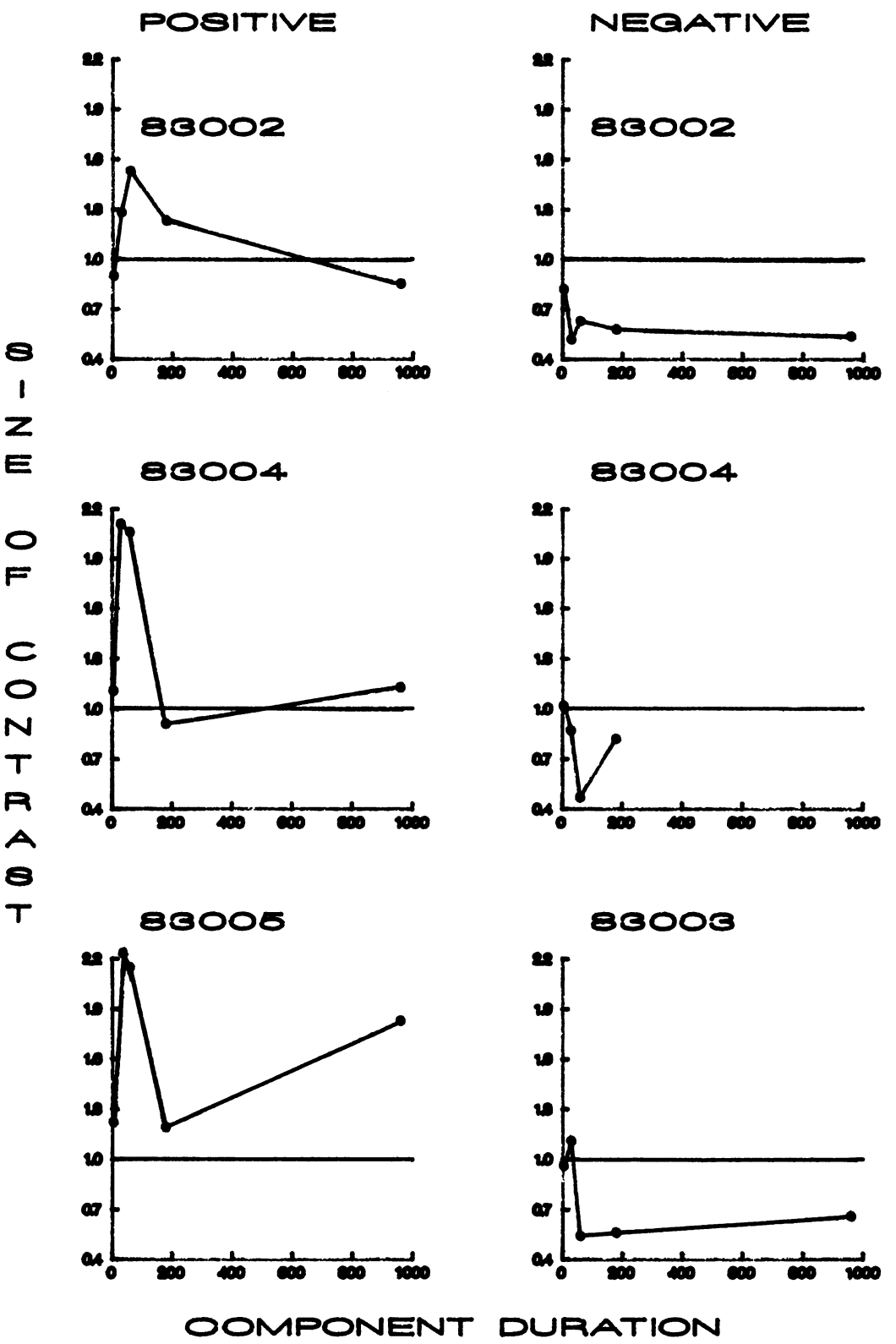
Fig. 1. The size of positive (left axes) and negative (right axes) contrast plotted as a function of the duration of the variable component in seconds (Experiment 1). The size of positive contrast was measured by dividing the rate of responding during the VI 2-min component of the multiple VI 2-min extinction schedule by the rate of responding during the same component of the multiple VI 2-min VI 2-min schedule. The size of negative contrast was measured by dividing the rate of responding during the VI 2-min component of the multiple VI 2-min VI 15-s schedule by the rate of responding during the same component of the multiple VI 2-min VI 2-min schedule. Each set of axes represents the results for a single subject.


POSITIVE
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S6002
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SIZE OF CONTRAST
COMPONENT DURATION

Table 2

Response rates (in responses per minute) emitted during each component of each multiple schedule in Experiment 2. Standard deviations appear in parentheses.

		Positive contrast					
		Subject					
		41		42		72	
Duration	Component	Baseline	Contrast	Baseline	Contrast	Baseline	Contrast
5 s	contrast	124.2 (8.7)	111.6 (21.0)	138.6 (18.7)	156.3 (5.9)	181.5 (15.6)	230.7 (23.8)
	variable	77.1 (6.7)	57.5 (11.4)	75.2 (8.7)	72.8 (9.4)	99.2 (9.0)	108.1 (5.9)
30 s	contrast	103.9 (17.8)	114.9 (12.6)	86.8 (5.8)	99.3 (9.5)	102.2 (20.1)	123.4 (28.0)
	variable	67.5 (14.7)	58.5 (20.9)	87.8 (12.3)	64.8 (16.5)	62.3 (21.6)	55.6 (25.4)
60 s	contrast	94.6 (4.1)	102.6 (4.0)	68.7 (6.2)	94.3 (5.0)	147.4 (5.1)	163.2 (18.8)
	variable	78.4 (4.4)	62.0 (8.6)	89.6 (12.7)	80.2 (6.5)	113.1 (10.2)	100.9 (16.5)
180 s	contrast	104.8 (5.6)	100.4 (8.2)	61.3 (20.9)	66.1 (14.4)	76.4 (7.5)	96.3 (11.3)
	variable	62.6 (12.9)	27.3 (19.3)	95.5 (22.8)	75.5 (12.8)	61.1 (14.1)	50.5 (16.6)
960 s	contrast	85.7 (5.3)	90.3 (1.8)	101.4 (5.1)	91.5 (4.0)	117.7 (1.8)	118.0 (4.3)
	variable	96.8 (11.9)	97.6 (25.5)	106.4 (11.8)	92.0 (14.4)	136.4 (28.1)	152.0 (22.1)

farthest from 1.0 for these component durations. However, Friedman nonparametric analyses of variance showed that the size of positive (Friedman statistic = 9.33, $df = 4$) but not negative (Friedman statistic = 4.20, $df = 3$) contrast changed significantly (statistically) with changes in the duration of the variable component. The test for negative contrast did not include the size of contrast for the 960-s components. As indicated, Subject 83004 stopped responding for this duration. Here and throughout this paper, results will be considered to be statistically significant when $p < .05$.

The relatively small size of positive contrast reported for Subject 83002 for the 5-s components and the relatively small size of negative contrast for Subject 83002 for the 180-s components may be an artifact of poor discrimination between the components. Good discrimination is required to produce contrast (e.g., Rachlin, 1973). As argued earlier, discrimination was relatively poor for these conditions.

EXPERIMENT 2

In Experiment 2, we examined the size of positive and negative key-peck contrast as a function of the duration of the component in which contrast is measured.

Method

Subjects. Three experimentally experienced pigeons, maintained at approximately 85% of their free-feeding body weights, served as subjects.

Apparatus. The apparatus was a two-key two-treadle experimental enclosure for pigeons, measuring 39 cm by 33 cm by 31 cm. The two response keys (2.5 cm diameter) were 22 cm above the floor and 12 cm apart. The left key was 11.5 cm from the left wall, and the right key was 10.5 cm from the right wall. An opening (6 cm by 5 cm) allowed access to a magazine containing mixed grain. It was located 5.5 cm above the floor and 17 cm from the right wall. A houselight (3 cm diameter) was 3.5 cm from the ceiling and 3.5 cm from the right wall. A floor treadle was located directly below each of the response keys. The treadles were not used in this experiment and will not be described.

The experimental panel was housed in a sound-attenuating chamber. A ventilating fan masked outside noises. Experimental events were programmed by a SYM® microcomputer located in another room.

Procedure. The procedure was identical to that used in Experiment 1, with the following exceptions. First, the components were presented on the left key. A white light (2.8 W) illuminated this key during the constant VI 2-min component; a green light (2.8 W) illuminated it during the variable component. Second, the duration of the variable component was held constant at 30 s. The duration of the contrast component changed across conditions. The contrast-component durations were conducted in the following order for positive con-

Table 2 (*Continued*)

Negative contrast					
Subject					
41		42		72	
Baseline	Contrast	Baseline	Contrast	Baseline	Contrast
68.6 (15.5)	31.6 (9.0)	91.4 (11.2)	45.6 (7.5)	95.9 (17.7)	74.7 (16.1)
60.6 (7.3)	60.3 (8.7)	104.0 (1.8)	106.7 (4.2))	76.7 (19.7)	94.0 (16.5)
67.0 (3.1)	49.5 (2.6)	81.4 (11.4)	47.5 (4.7)	105.0 (8.3)	83.9 (4.0)
65.8 (8.4)	70.8 (4.0)	96.8 (11.0)	83.9 (3.0)	98.0 (10.2)	108.2 (7.3)
69.8 (4.4)	67.1 (7.9)	76.5 (10.5)	54.0 (9.6)	88.9 (12.5)	69.3 (29.2)
79.6 (8.8)	91.9 (6.6)	101.0 (3.9)	80.0 (5.8)	104.4 (18.8)	117.2 (17.5)
83.8 (4.9)	81.0 (2.5)	82.9 (10.5)	70.8 (5.2)	94.7 (9.6)	98.4 (4.0)
76.7 (8.2)	75.0 (8.8)	97.4 (10.9)	81.9 (11.3)	118.2 (15.0)	137.4 (8.8)
76.8 (3.0)	79.4 (7.0)	88.7 (10.4)	79.4 (6.1)	117.2 (5.1)	108.3 (4.6)
101.2 (10.6)	71.6 (13.3)	99.6 (25.8)	83.2 (16.2)	137.2 (4.8)	136.0 (8.6)

trast: 180 s, 30 s, 5 s, 60 s, and 960 s. The component durations were presented in the following order for negative contrast: 180 s, 30 s, 960 s, 5 s, and 60 s. The same number of components were presented per session for each of these component durations, as in Experiment 1. Again, each duration was presented for 30 sessions.

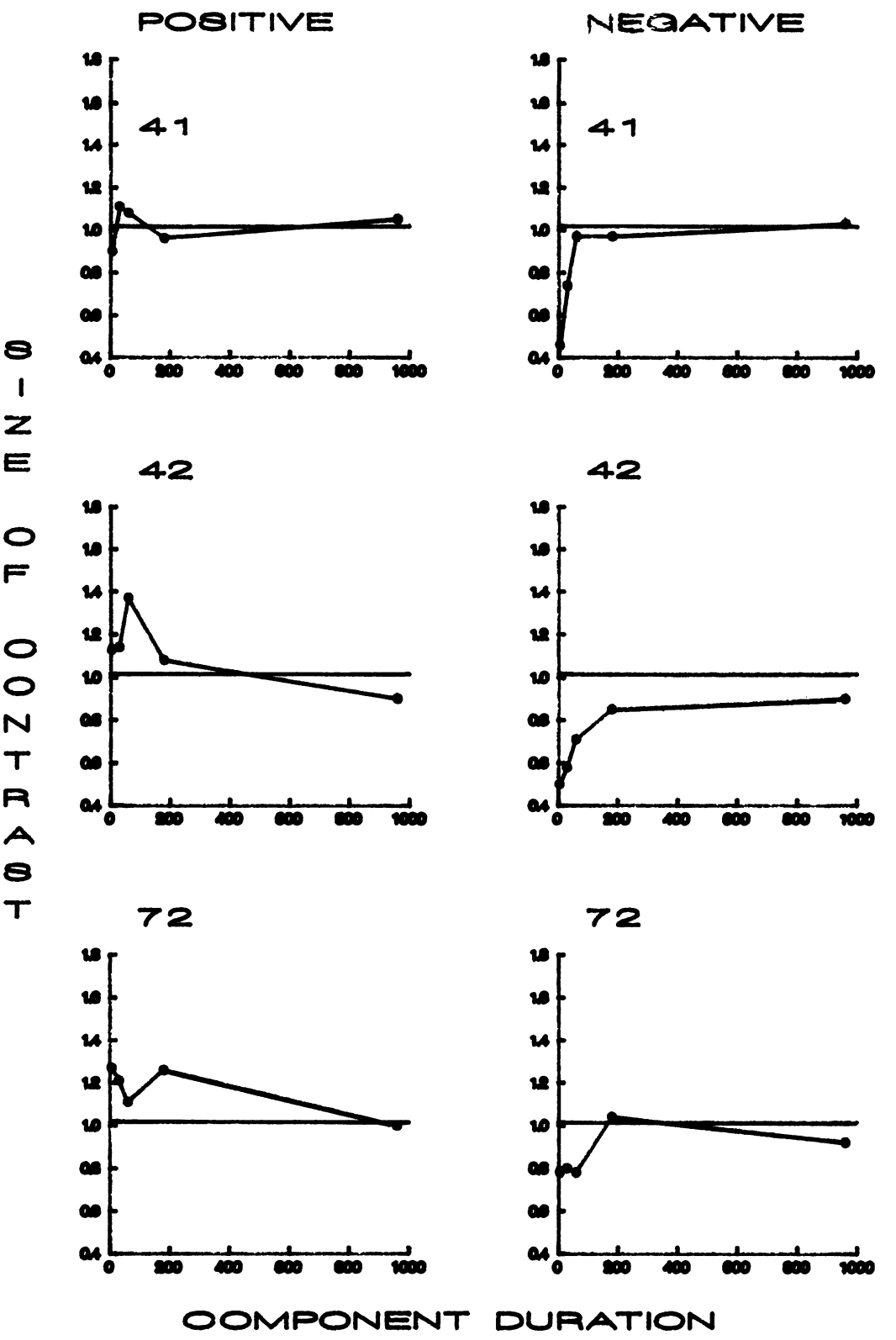
Results and Discussion

Table 2 presents the rates of responding (in pecks per minute) for each subject and for the mean of all subjects responding on each component of each multiple schedule. It shows that responding was stable. The standard deviations were small (M = 11.0) relative to the response rates themselves (M = 91.4). Discrimination between the components of the contrast schedules was also good, except when the contrast component was 960 s long. The rates of responding during the VI 2-min components of the contrast schedules were greater than the rates during the extinction components in 11 of 15 cases for individual subjects. Three of the four exceptions occurred for the 960-s component duration. The only other exception occurred for Subject 42 with the 180-s component. The rates of responding during the VI 15-s components of the contrast schedules were greater than the rates during the VI 2-min components in 13 of 15 cases. However, the differences in rates were small for the 960-s components.

Response rates decreased in the variable component when this component changed from a VI 2-min to an extinction schedule in 12 of 15 cases for individual subjects. Response rates did not consistently increase in the variable component when that component changed from a VI 2-min to a VI 15-s schedule. Response rates increased in only 7 of 15 cases for individual subjects. Decreases in response rates during high rates of reinforcement are not unusual. They have been observed in other experiments (e.g., Dougan & McSweeney, 1985; McSweeney & Melville, 1991a), and they are consistent with several theories (e.g., Baum, 1981; Staddon, 1979).

Table 2 shows that positive and negative contrast often occurred. Response rates increased during the contrast VI 2-min component when the variable component changed from VI 2 min to extinction in 12 of 15 cases for individual subjects (positive contrast). Response rates decreased during the contrast VI 2-min component when the variable component changed from VI 2 min to VI 15 s in 13 of 15 cases (negative contrast).

Figure 2 presents the size of positive and negative contrast plotted as a function of the duration of the contrast component (in seconds). An inconsistent picture emerges for positive contrast. The size of positive contrast was greatest for the 30-s component for Subject 41, for the 60-s component for Subject 42, and for the 5- or 180-s components for Subject 72. A Friedman nonparametric analysis of variance applied to these points confirms statistically


POSITIVE
NEGATIVE
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41
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SIZE OF CONTRAST
COMPONENT DURATION

that the size of positive contrast did not change significantly with changes in the duration of the contrast component (Friedman statistic = 7.40, $df = 4$).

The absolute size of negative contrast decreased with increases in component duration up to 60 or 180 s for all subjects. Then it remained unchanged with further increases in component duration. The changes in the size of negative contrast with changes in constant-component duration were statistically significant (Friedman statistic = 9.67, $df = 4$).

The results plotted in Figure 2 for both positive and negative contrast for the 960-s components may have been produced by a failure of discrimination. Again, good discrimination is required for contrast. Table 2 shows that discrimination was poor during the contrast schedules for these component durations.

GENERAL DISCUSSION

Changing the duration of the variable component produced significant changes in the size of positive contrast. The median size of positive contrast was 1.11, 2.11, 2.06, 1.19, and 1.13 for the 5-s, 30-s, 60-s, 180-s, and 960-s variable components, respectively (Experiment 1). The size of positive contrast did not change significantly with changes in the duration of the contrast component (Experiment 2). The increases followed by decreases in positive contrast with increases in component duration are consistent with the results of a previous within-session study in which the duration of both components changed (e.g., McSweeney & Melville, 1988).

Changing the duration of the contrast component produced significant changes in the size of negative contrast. The median size of negative contrast was 0.50, 0.74, 0.78, 0.97, and 0.92 for the 5-s, 30-s, 60-s, 180-s, and 960-s contrast components, respectively (Experiment 2). The size of negative contrast did not change significantly with changes in variable-component duration (Experiment 1). These decreases in the absolute size of negative contrast with increases in component duration are consistent with the results of a previous across-session study in which the duration of both components varied (e.g., McSweeney, 1982).

The factors that produced the present changes in the size of contrast are not known. However, many explanations can be dismissed. The changes were not produced by systematic changes in discrimination. Discrimination ratios were calculated for each contrast schedule by dividing the rates of responding during the contrast component by the sum of the rates of responding during both components. Friedman nonparametric analyses of variance showed that these ratios did not change significantly (statistically) with changes in component duration in Experiment 1 (Friedman statistic = 6.33, $df = 4$ for positive contrast; Friedman statistic = 1.87, $df = 4$ for negative contrast) or Experiment 2 (Friedman statistic = 7.13, $df = 4$ for positive contrast; Friedman statistic = 8.55, $df = 4$ for negative contrast).

Changes in session length did not produce the present results. Different numbers of components were presented per session for different component durations to hold session length as constant as possible (see McSweeney, 1992). Sessions were 35, 36, 36, 35, and 33 min long when the component that was varied was 5, 30, 60, 180, or 960 s long, respectively. Such small changes in session length would be unlikely to produce the present large changes in the size of contrast.

Trying to hold session length constant produced systematic changes in several other factors. The number of components presented per session were 120, 72, 48, 20, and 4 for the 5-s, 30-s, 60-s, 180-s, and 960-s components, respectively. The component that was held constant at 30 s was available for 30, 18, 12, 5, and 1 min per session when the other component was 5, 30, 60, 180, and 960 s long. The component that was varied was available for 5, 18, 24, 30, and 32 min per session when its duration was 5, 30, 60, 180, or 960 s. However, none of these changes produced the pres-

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Fig. 2. The size of positive (right axes) and negative (left axes) contrast plotted as a function of the duration of the contrast component in seconds (Experiment 2). The size of contrast was measured and reported as in Figure 1. Each set of axes represents the results for a single subject.

Table 3

The rates of responding emitted during the contrast components for the mean of all subjects in Experiments 1 and 2.

Change in duration of the leaner component					Change in duration of the richer component				
Leaner component duration	Positive contrast (Experiment 1)		Negative contrast (Experiment 2)		Richer component duration	Negative contrast (Experiment 1)		Positive contrast (Experiment 2)	
	Baseline	Contrast	Baseline	Contrast		Baseline	Contrast	Baseline	Contrast
5	46.9	49.3	85.3	50.6	5	45.9	42.1	148.1	166.2
30	51.3	89.1	84.5	60.3	30	25.4	19.9	97.6	112.5
60	28.3	52.1	78.4	63.5	60	29.1	16.4	103.6	120.0
180	67.7	74.6	87.1	83.4	180	27.9	17.6	80.8	87.6
960	67.9	73.3	94.2	89.0	960	20.3	12.1	101.6	99.9

ent results. To begin with, these monotonic changes have difficulty accounting for the nonmonotonic changes in the size of contrast reported in Experiment 1. Furthermore, these changes occurred in the same manner for Experiments 1 and 2, but the results were different for the two studies (see Figures 1 and 2).

The order in which the conditions were conducted cannot account for the present results. The median size of contrast usually varied erratically with the order in which the conditions were conducted. The only exception occurred for positive contrast in Experiment 1. Its size was 2.06, 2.11, 1.19, 1.11, and 1.13 when results are presented in the order conducted. However, running order does not provide an adequate explanation even for these results. It cannot explain why the size of positive contrast increased and then decreased with increases in component duration in both Experiment 1 and in the study by McSweeney and Melville (1988, Experiment 1). Similar results were reported in the two studies, even though component durations were presented in different orders.

Finally, the results are not an artifact of conducting the contrast phase of the experiment after the baseline phase. For example, differences in satiation or fatigue for different component durations might produce differences in response rates and, therefore, differences in the size of contrast. However, two considerations question this idea. First, as will be discussed below, the results of the present experiments are similar in detail to those reported by Ettinger and Staddon (1982) and Wilton and Clements (1971), neither of which presented a contrast schedule after a baseline phase. Second, examination of subjects' body weights for different component durations provides no evidence of differential satiation. Satiation would be most likely to occur during the longer components in the negative contrast phase. The rich VI 15-s component was sometimes available for long periods during those conditions. However, the mean weights of the subjects were 307, 314, 309, 309, and 314 g for the 5-s, 30-s, 60-s, 180-s, and 960-s components in Experiment 1, respectively. They were 365, 362, 367, 366, and 353 g for the same components in Experiment 2. The relative constancy of the subjects' weights questions the idea that satiation changed systematically with component duration.

The changes in the absolute rates of responding that produced the present changes in contrast are complicated. Although there is a large amount of variance in the data, the changes in the absolute rates of responding during the contrast components are best summarized by citing changes in the duration of the leaner or richer components. The rates of responding during the contrast components tended to increase with increases in the duration of the leaner component. Table 3 (left side) summarizes the results for positive contrast in Experiment 1 and negative contrast in Experiment 2. Contrast-component response rates generally decreased with increases in the duration of the richer component. Table 3 (right side) summarizes these results for negative contrast in Experiment 1 and positive

contrast in Experiment 2. (All results are those for the mean of all subjects. Results for individual subjects appear in Tables 1 and 2.)

The changes in variable-component response rates are more easily summarized by citing the component that varied in duration. That is, rates of responding during the variable components generally decreased with increases in their own duration in Experiment 1 (see Table 4, top). Variable-component response rates generally increased with increases in the duration of the other component in Experiment 2 (see Table 4, bottom).

These changes in absolute response rates are complicated and would have to be doubted except that they are consistent with the results of past across-session studies that varied the duration of only one component of a multiple schedule. Wilton and Clements (1971) found that the rate of responding during a VI 1-min schedule was higher the longer the duration of a preceding extinction component. This is compatible with the data in Table 3 (left side) (positive contrast).

Ettinger and Staddon (1982) studied changes in the rates of responding during the components of a multiple VI 60-s VI 240-s schedule when the duration of each component varied independently from 10 to 180 s. They concluded that the rate of responding during the richer component decreased with increases in its duration. This is compatible with Table 3 (right side) (positive contrast) and with Table 4 (top) (negative contrast). Response rates during the leaner component increased with increases in its own duration. This is compatible with Table 3 (left side) (negative contrast). These comparisons, and all of those that follow, should be made to the results presented in Tables 3 and 4 for the contrast schedules only. The baseline schedules did not provide richer and leaner schedules.

Ettinger and Staddon (1982) also reported that response rates did not change significantly with changes in the duration of the other component, but the trends that appear in their data are also apparent here. In their study, the rate of responding during the richer component generally increased with increases in the duration of the other component. This is compatible with Table 3 (left side) (positive contrast) and Table 4 (bottom) (negative contrast). The rate of responding during the leaner component generally decreased with increases in the duration of the other component. This is compatible with Table 3 (right side) (negative contrast).

Table 4

The rates of responding emitted during the variable components for the mean of all subjects in Experiments 1 and 2.

	Positive contrast		Negative contrast	
	Baseline	Contrast	Baseline	Contrast
Variable-component duration (Experiment 1)				
5	50.5	28.9	80.5	102.6
30	28.3	17.3	39.0	88.4
60	32.8	28.5	51.6	78.7
180	42.9	26.1	29.7	33.4
960	36.2	16.1	20.3	54.2
Contrast-component duration (Experiment 2)				
5	83.8	79.5	80.4	87.0
30	72.5	59.6	86.9	87.6
60	93.7	81.0	95.0	96.4
180	73.1	51.1	97.4	98.1
960	113.2	113.9	112.7	96.9

The only difference in results between the two studies occurred when responding during our extinction components was compared to responding during Ettinger and Staddon's (1982) VI 240-s schedule. Response rates during their VI 240-s component increased with increases in its own duration. This is not apparent for extinction in Table 4 (top) (positive contrast). Response rates during the VI 240-s component also decreased (but were not statistically significant) with increases in the duration of the other component. This is not apparent for extinction in Table 4 (bottom) (positive contrast). These differences could be explained if different factors controlled responding during extinction and during a lean schedule of reinforcement. For example, factors that are too weak to control responding on a schedule may gain control of behavior during extinction.

The present experiments show that changing the duration of the variable component has the largest effect on the size of positive contrast (Experiment 1), but changing the duration of the contrast component has the largest effect on the size of negative contrast (Experiment 2). These results challenge symmetry theories of contrast. However, one summary of the present results could reconcile them with a

symmetry theory. The results indicate that the component that provides the lower rate of reinforcement has the greatest influence on the size of both positive and negative contrast. That is, the size of positive contrast was controlled by the duration of the component that provided extinction. The size of negative contrast was controlled by the duration of the component that provided the VI 2-min schedule. To the best of our knowledge, no theory currently predicts that the leaner component exerts a stronger influence on the size of contrast. Therefore, current symmetry theories may require modification.

One way to rescue symmetry theories might be to dismiss the present results as an artifact of the use of the within-session procedure. There are many reasons why the within-session and the more conventional across-session procedures might produce different results. For example, responding during the variable component is extinguished throughout training when the within-session procedure is used to study positive contrast. Responding is extinguished only during the first few sessions in the across-session procedure. Therefore, the results of the two procedures would differ if a factor related to the introduction of extinction (e.g., frustration) played a role in producing positive contrast.

The present experiments should be replicated using an across-session procedure to test this possibility. However, for now, it is difficult to dismiss the present results as an artifact of any aspect of the within-session procedure. The present results are remarkably similar to those reported by Wilton and Clements (1971) and Ettinger and Staddon (1982) using across-session procedures. The similarities are sufficiently detailed that they are unlikely to have been produced by coincidence. Instead, they suggest that the within- and across-session procedures may govern behavior in fundamentally similar ways.

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